Industry Requirements for Broad Band EUV Sources for Next-generation Wafer Inspection Applications

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Background – Problem Definition

- For detecting smaller defects for next -generation wafer inspection technology, we will benefit from reduction of wavelength used for inspection
  - Current wavelength of > 193 nm from broadband plasma sources and lasers
- Plasma sources radiate in wide regions (water window- IR)
- Metrology source suppliers are looking for alternative applications for their sources
  - Water Window has been explored, e.g., at UCD

Background – Three Pieces of Puzzle

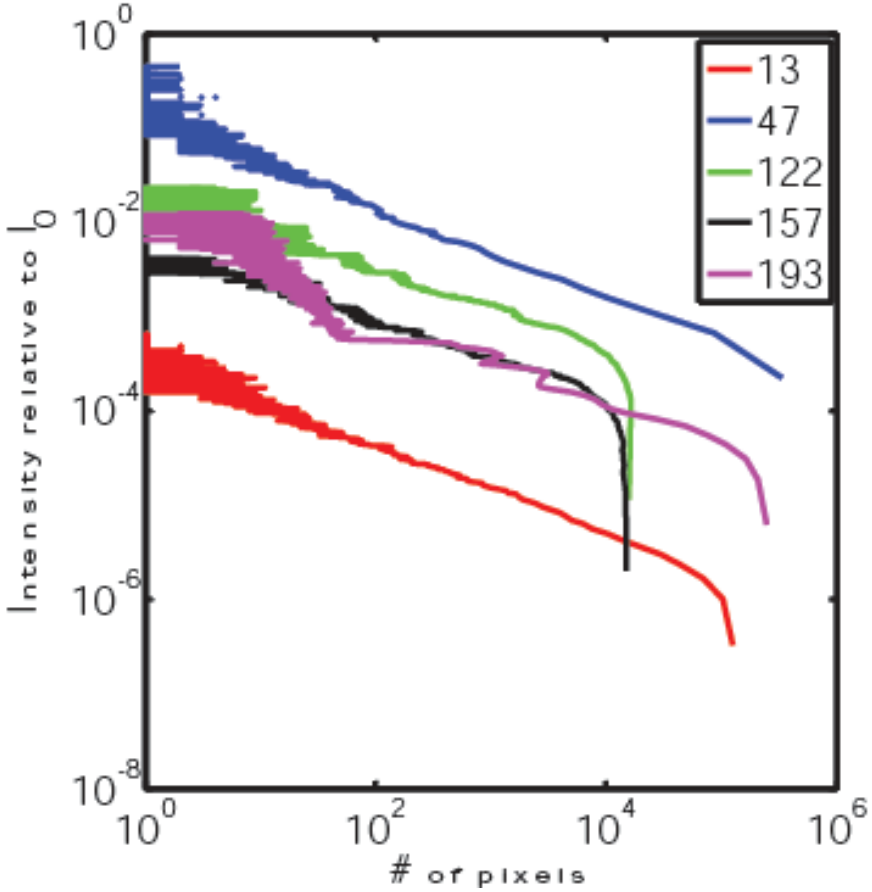
- There are three parts of the solution
  - First - Understand benefit of wavelength switch and identify wavelength for plasma sources and lasers
  - Second –
    - A: Understand source characterization – current and define future requirements
    - B: Understand performance of optics in this wavelength region
  - Third – Understand Business Aspects and Cost of Ownership

Background - Pieces of Puzzle

- Task assigned by Source TWG in 2016 Source Workshop
  - What is the wavelength(s) of interest?
  - What are the power and brightness requirements?
- Approached source makers, integrators and leading -edge chip makers for feedback on requirements
- Received total of five inputs to generate draft proposal for the community

Proposals for wavelength – NIST Study

- Investigated
  - Vacuum UV 122 and 157 nm
  - Extreme UV 47 and 13.5 nm
- Relative Sensitivity of reflected signal
  - 47 > 122>193>157> 13.5
- 47 nm S/N is ~ 5 x than 193 nm
  - 13.5 nm n~1 and k~0, 47 nm
  - 47 nm has larger k and metallic n



$$I = \left(\frac{1+cos^2\theta}{2R^2}\right)\left(\frac{2\pi}{\lambda}\right)^4\left(\frac{|\tilde{n}|^2-1}{|\tilde{n}|^2+2}\right)^2\left(\frac{d}{2}\right)^6 I_{}$$

Ref: Bryan Barnes, SPIE Vol. 10145, 1014511-1, March 2017

Plasma Source Performance 30-180 nm

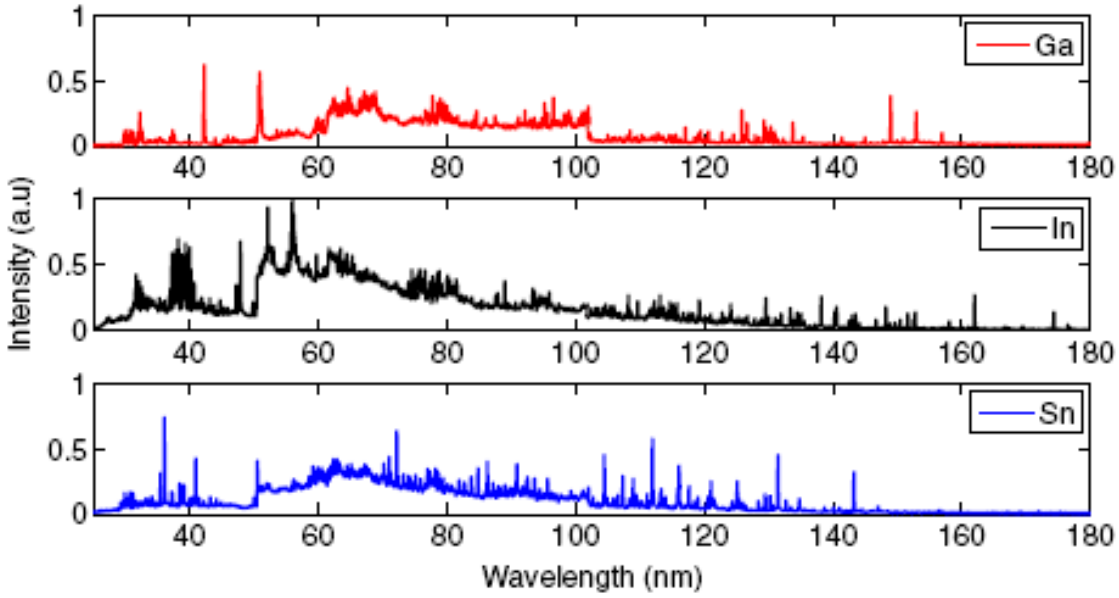


Fig. 4 Emission spectra of the three fuels, gallium, indium, and tin in the VUV region from 30 to 160 nm.

Table 1 Integrated power calculated for the different fuels in different wavelength ranges.

Wavelength range (nm)	Ga (W)	In (W)	Sn (W)
30–100	0.72 ± 0.06	3.41 ± 0.30	1.88 ± 0.16
100–180	2.02 ± 0.17	2.62 ± 0.23	2.06 ± 0.18
30–180	2.73 ± 0.23	6.03 ± 0.52	3.94 ± 0.34

R. Abhari et al, JM3, Vol 14 (3), Jul-Sept 2015

Additional Feedback

- Inspection wavelength >100 nm (very high absorption <100 nm)
- For patterned inspection, contrast is very important
- Broadband source preferred for patterned wafer inspection
  - Success of KT tools
- Lasers are preferred for wafer blank inspection
  - < 170 nm and CW or MHZ operation preferred
- 50-120 nm is preferred region
- For plasma sources, focus on narrow bandwidth helps to optimize power
- LPP sources are sufficiently small emitting volume and bright for application
- Wide range of feedback on cost of ownership requirements
- Yes, we are working on it but cannot discuss wavelengths at this time!

Requirements for Next-generation Optical Wafer Inspection Tool (Draft Proposal to Guide EUV Source Makers and Researchers) (2017 Source Workshop)		
Parameter	**Units**	**Value /Comments**
Metrology Source Requirements (Wafer Inspection tool)		
Source Wavelength (Plasma)	nm	47 -150 (Plasma) ; < 170 nm (Lasers)
Bandwidth	+/- %	BB is Preferred for plasma sources. Need to know around which wavelength to optimize the source
Source Etendue	mm^2sr	TBD
Brightness	$W/mm^2/sr$	>100
Power	W	>100 for plasma, few W for CW lasers
Energy stability	%	<1 %
Pulse repetition rate	TBD	MHz to CW preferred to avoid damage
Duty cycle		>95 %
Optical Wafer Inspection Metrology Tool Requirements - Performance and CoO (Independent of Wavelength /Tool type)		
Defect Sensitivity (7 -3 nm node)	nm	<5-7 (smaller for 3-5 nm node) Focus on 3 nm node, where we can make the impact
Throughput (Un-patterned)	WPH	100 -150 (Based on CoO)
Throughput (Patterned)	WPH	30-40 (Based on CoO)
Availability	%	>95 %

Summary – Key points

- Vacuum UV and Extreme UV sources are of interest for next-generation wafer inspection
- We have received feedback from various members of community (chip makers, integrators and source suppliers)
- Draft proposal for specs is generated to start discussion and provide guidance to source community. Draft will be updated, per feedback
- Choice of photon sources will depend on several factors
  - Wavelength
  - power @ chosen wavelength
  - Optics
  - Do we adjust wavelength to match the optics to maximize S/N, instead of throughput?
  - Inspection performance at chosen wavelength
  - **Cost of ownership and business case**

Summary – Suggested Next Steps

- Characterization of absolute power and brightness of plasma sources in 47-150 nm region (plasma and lasers)
- Review of optics (ML) performance in the 50-150 nm region
- Review of lasers technology for <170 nm
- Continued modeling efforts to understand wafer inspection performance at wavelengths < 193 nm
- Papers on these topics will be invited in the next workshop
- Continued discussion with all stake holders on specs for “Photon Sources for wafer inspection tools for next generation”